DRAFT
SENTRY MILK-VETCH
(*Astragalus cremnophylax* Barneby
var. *cremnophylax* Barneby)
RECOVERY PLAN

U.S. Fish and Wildlife Service
Albuquerque, New Mexico
2004

SENTRY MILK-VETCH

(*Astragalus cremnophylax* Barneby var. *cremnophylax* Barneby)

RECOVERY PLAN

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The cover photograph is used with the kind permission of the photographer, Peter Rowlands.

EXECUTIVE SUMMARY

Current Status: Sentry milk-vetch is listed as endangered and is known from two, and possibly three, locations on the South Rim and one location on the North Rim of Grand Canyon National Park (Park). As of 2001, the original population at Maricopa Point contained approximately 665 individuals. This population was in severe decline until 1990 when a protective fence was erected. Following protection, plant numbers began to stabilize, and, by 1994, the population began to exhibit a modest upward trend. The primary cause of population decline prior to protection was trampling by Park visitors, though drought conditions may have worsened the situation. Some degree of trampling continues as some visitors violate the exclosure. Upon its discovery in 1991, a smaller population on the South Rim east of Grandview Point consisted of three plants. In 2001, that population consisted of two plants. Surveys completed in 2003-04 have not relocated the two plants at Grandview and this population is thought to have died out. In 1994, a third population of approximately 1,000 plants was discovered on the North Rim of the Grand Canyon and identified as the listed variety based on morphological characteristics. Recent preliminary research suggests that this population may be worthy of varietal or other taxonomic distinction. In 2002, what may be an additional population was discovered on the South Rim of the Canyon at "Lollipop" Point. Although the individuals in these populations appear to be of the listed variety, they have not yet been positively identified as such. Specimens were collected during the 2003 reproductive season for identification and taxonomic purposes. There are approximately 250 individuals at Lollipop Point.

Habitat Requirements and Limiting Factors: Sentry milk-vetch is known primarily from areas where Kaibab limestone forms large flat platforms with shallow soils near pinyon-juniper woodlands. The Kaibab limestone at Maricopa Point may have high porosity and perhaps high water retention that aids in plant growth. The species' habitat specificity, reduced number and vigor of plants, and small habitat size make it vulnerable to extinction. The major threats to the species include habitat destruction and modification, decreased population numbers, extreme rarity, and low reproduction.

Recovery Objective: The ultimate objective of this plan is to delist sentry milk-vetch. Recovery actions in the Plan will ensure the species' survival.

Recovery Criteria: In order to **downlist** the species, achieve, maintain, and provide long-term protection for at least four viable sentry milk-vetch populations of at least 1,000 individuals each, for a total of at least 4,000 individuals, in the wild. Each natural population must be stable or increasing over a ten-year period. Each artificially established population must be stable or increasing over a thirty-year period. Protect each population from threats. **Recovery** (delisting) will be attained when there are eight viable sentry milk-vetch populations of 1,000 individuals each, with long-term protection. Each natural population

must be stable or increasing over a ten-year period and each artificially established population must be stable or increasing over a thirty-year period. Protect each population from threats. Assess the species' status and threats by monitoring populations and the effects of the threats.

Major Actions Needed:

1. Protect all populations from threats.
2. Survey potential habitat to determine if other populations exist.
3. Maintain and manage natural populations to their maximum potential.
4. Conduct research on biology and ecology to determine the species' requirements.
5. Establish and maintain a botanical garden/greenhouse population program.
6. Establish new populations as necessary to meet recovery criteria
7. Provide assistance to protect and recover the species and its habitat.
8. Develop public awareness and support for preservation of the species.
9. Exchange information among partners.

These actions are not necessarily listed in order of priority. Prioritized stepped-down actions are provided in the Implementation Schedule. The Major Actions Needed translate directly to the step-down of Recovery Actions and Narrative Outline of Recovery Actions.

Total Cost of Downlisting (minimum for first five years)): $648,000

Costs, in thousands of dollars:

Year	Minimum Costs: ($000s)
2005	162
2006	157
2007	107
2008	111
2009	111
2010+	To be determined

The estimated cost of each recovery task is provided in the Implementation Schedule of this recovery plan.

Date of Recovery: Time to achieve recovery is unknown. Time to reclassification will be based on the time it will take to survey existing habitat, accomplish priority research needs, establish a botanical garden population, establish new wild populations, and implement management to protect the species. Estimated time to delisting is contingent upon results obtained during the downlisting recovery period. Success in protection and establishment of populations will help determine the remaining effort necessary to reach recovery. Progress on major actions will be assessed in five years (2009-10), and the plan will be reevaluated and revised as necessary.

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PART I - INTRODUCTION

Brief Overview

Sentry milk-vetch (*Astragalus cremnophylax* Barneby var. *cremnophylax* Barneby) was listed as an endangered species on December 5, 1990 (U.S. Fish and Wildlife Service 1990). It is a rare endemic known only from two, and possibly three, locations on the South Rim, and one location on the North Rim, of the Grand Canyon, Coconino County, Arizona, within Grand Canyon National Park (Park). Marcus E. Jones first discovered the species in 1903, but he mistakenly identified it as *A. humillimus* and reported it as "apparently common at the Grand Canyon . . . on sandy ledges." In 1947, Barneby and Ripley recollected the species 3.2 kilometers (two miles) west of El Tovar, a hotel on the South Rim. Their collection was probably taken at Maricopa Point, where the largest known population on the South Rim exists. Barneby (1964) described the population of perhaps 100 individuals as being confined to a strip of Kaibab limestone pavement not over 46 meters (50 yards) in length. Additional surveys for the species did not locate any other populations until 1991, when three plants were discovered near Grandview Point by Therean Taylor of the Park. Thus, assuming Marcus E. Jones was correct about the species' condition in 1903, the species' status may have diminished from "common" to "rare" in 44 years.

Permanent study plots for annual population monitoring were established in 1988 at Maricopa Point (Brian 2000b and 2001). At that time, there were 361 individual plants within the monitoring plots (about 75 percent of the estimated total population). Of those, 58 percent were severely damaged, apparently due to trampling by Park visitors at this popular canyon overlook. Trampling resulted in plant loss and habitat degradation. By the time a protective fence was erected in 1990, the number of plants within the monitoring plots had declined to 285. The effects of trampling persisted after fencing, and the number of plants within the plots continued to decline to 278 in 1991. The number of plants then stabilized, and by 1994, a modest upward trend was evident with 337 individuals in the 1994 monitoring plots (U.S. Fish and Wildlife Service 1992, Maschinski and Rutman 1993, Warren 1993, Maschinski *et al.* 1994, Warren 1994). Monitoring conducted in 2000 resulted in detection of a total of 683 plants at Maricopa Point and two plants at the site near Grandview Point (Brian 2000). Monitoring conducted in 2001 indicated that a total of 665 plants existed at Maricopa Point and the two remained at the site near Grandview Point (Brian 2001). The most recent monitoring completed (2004) has shown a continuing decline in plants at Maricopa Point, with only 376 plants detected. The Grandview population is now thought to be extirpated, as the two known individuals were not relocated in 2003-04 surveys (Juarez-Cummings 2004).

In 1994, a third population of what has been identified, based on morphological characteristics, as sentry milk-vetch was discovered on the North Rim of the Grand Canyon (Brian 2000b). Up to five subpopulations, totaling approximately 1,000 plants occur at this

location. Recent preliminary information suggests that this population may be worthy of varietal or other taxonomic distinction (Allphin *et al.* undated, Allphin *et al.* in prep.).

In 2002, as a result of surveys conducted for construction projects in the Park, possibly an additional population of the species was discovered on the South Rim. What has been referred to as the "Lollipop" Point population occurs between Maricopa Point and Grandview Point. That population contains a total of approximately 250 individuals in three subpopulations. Positive identification of individuals from this population based on morphological characteristics is pending based on a 2003 collection of flowers and fruits.

Sentry milk-vetch has a U.S. Fish and Wildlife Service (Service) recovery priority of 3. Recovery priorities assigned to listed species range from 1 to 18, with species ranking 1 having the highest Service recovery priority.

This plan outlines the steps necessary to achieve, maintain, and document long-term stability of sentry milk-vetch by removing threats, enhancing existing populations, and possibly creating new populations if needed. Attainment of these goals will lead to the recovery of the species.

Taxonomy and Description

Although Jones made the first collection of *Astragalus cremnophylax* in 1903, the species was not described until 45 years later (Barneby 1948). With typical style, Barneby assigned a specific epithet that describes the dramatic site occupied by the species. The English translation of the Latin word *cremnophylax* means "watchman of the gorge." In 1979, Barneby described a new variety, *A. cremnophylax* var. *myriorrhaphis*, from plants discovered by Ralph Gierisch and associates in 1978, on Buckskin Mountain, Coconino County, Arizona (Barneby 1979). A third variety, *A. cremnophylax* var. *hevronii*, was also described by Barneby (1992). *A. cremnophylax* var. *hevronii* was discovered in 1991 by Bill Hevron of the Navajo Natural Heritage Program, on the east rim of Marble Canyon, Coconino County, Arizona. After the discovery of variety *myriorrhaphis*, the group of plants containing the type-specimen of the species was automatically assigned the name *A. cremnophylax* var. *cremnophylax*.

A. cremnophylax and three other species are in the subsection *Humillimi* of the genus *Astragalus*, family Fabaceae (pea family). Plants in this subsection have silvery-haired leaves and stems. Flowers have short, campanulate calyxes with pale, purplish-pink petals and white-tipped wings. The cushion-shaped *Humillimi* appear to be derived from *A. gilensis* or from a similar and recent common ancestor and have retained nearly all the basic features of flower, fruit, stipule, and hair-attachment, but are reduced in size or in numbers of nearly all organs (Barneby 1964).

A. cremnophylax is distinguished from other species in the subsection *Humillimi* by its compact, 3 to 12 millimeter (0.1 to 0.5 inch) long, pinnately compound leaves that bear 5 to 9 minute leaflets, and small white to pale-purple flowers with banners 5 to 6 millimeters (0.2 inch) and keels not over 4.5 millimeters (0.2 inch) long. Pistils have 4 to 6 ovules. Its pods are 3.0 to 4.5 millimeters (0.1 to 0.2 inch) long, obliquely egg-shaped and densely hairy (Barneby 1964).

Several characteristics distinguish variety *cremnophylax* from the varieties *myriorrhaphis* and *hevronii*. Both of the varieties *myriorrhaphis* and *hevronii* are somewhat larger and coarser than variety *cremnophylax*. Variety *myriorrhaphis* has leaves that are 13 to 35 millimeters (0.5 to 1.4 inches) long, which is three to four times the length of mature variety *cremnophylax* leaves. Variety *myriorrhaphis* has leaves that are dimorphic within a growing season; early season leaves are short and soft and late season leaves are stiffly erect and leaf stalks harden and become prickly after the leaflets fall (Barneby 1979, Cronquist *et al.* 1989). Variety *hevronii* is rather similar to variety *myriorrhaphis* in foliage, but has larger flowers of brighter color. Figure 1 illustrates the growth habit, leaf, and flower of *A. cremnophylax* var. *cremnophylax*. The three varieties are also distinguished by their geographic ranges. *A. cremnophylax* var. *myriorrhaphis* is known from several sites along the north Kaibab Plateau, *A. cremnophylax* var. *hevronii* is known from two sites on the rim of Marble Canyon, and the distribution of *A. cremnophylax* var. *cremnophylax* is as described below.

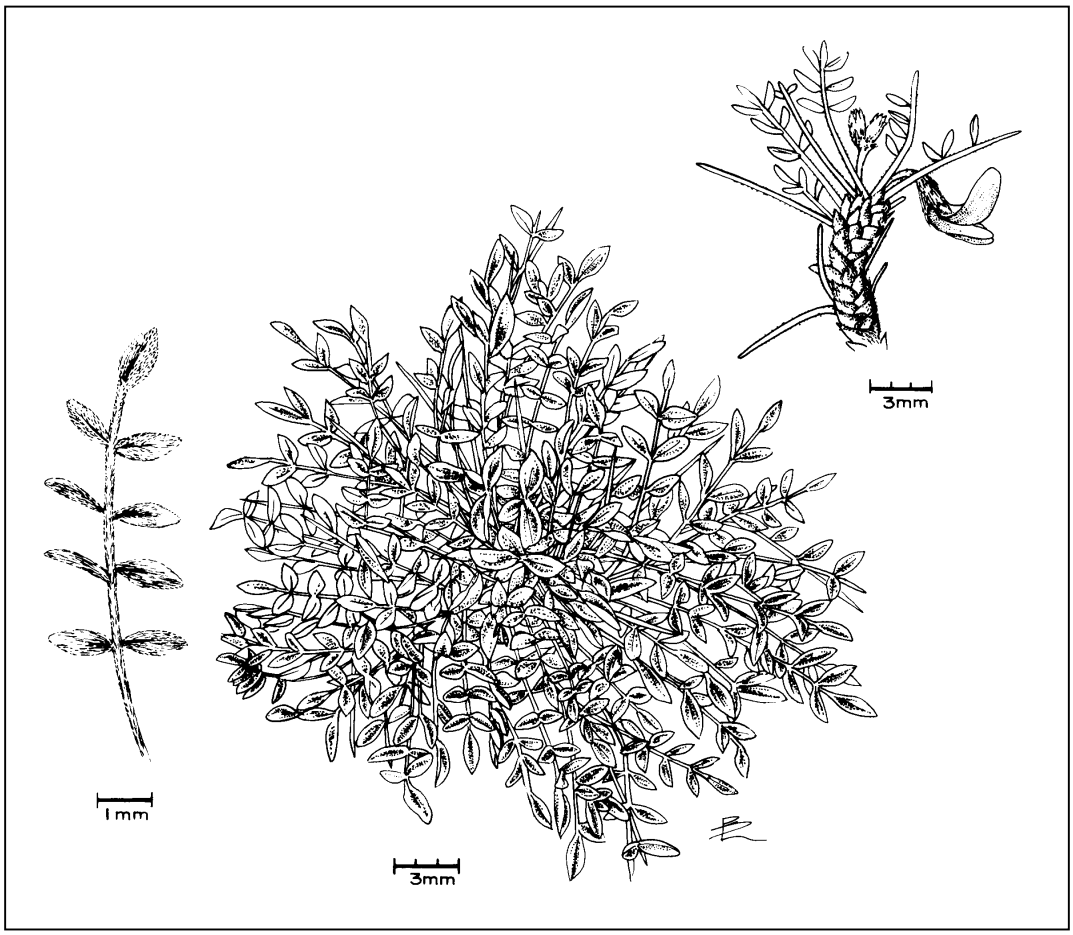

Figure 1. The growth habit, leaf, and flower of sentry milk-vetch.

Distribution

Sentry milk-vetch is currently known from two, and possibly three, locations on the South Rim and one location on the North Rim of the Grand Canyon (Figure 1). The largest population on the South Rim, of approximately 376 individuals in 2004, occurs at Maricopa Point and has been known since its discovery in 1903. The population has decreased by approximately 56% since 2001, when 665 plants were located. Surveys for the plant have been conducted for many miles in each direction from this population (U.S. Fish and Wildlife Service 1990, Maschinski 1992, Warren 1993). No new populations were discovered until 1991, when three plants were found at a site east of Grandview Point (Warren 1993), a straight-line distance of approximately 20 kilometers (12.5 miles) from Maricopa Point. Further surveys at Grandview Point in 1993 resulted in the discovery of a total of six plants in a localized area (K. Warren *in litt.* 1993). As of 2001, only two plants existed at the Grandview Point site (Brian 2001). As of 2004, plants no longer exist at this location (Juarez-Cummings 2004).

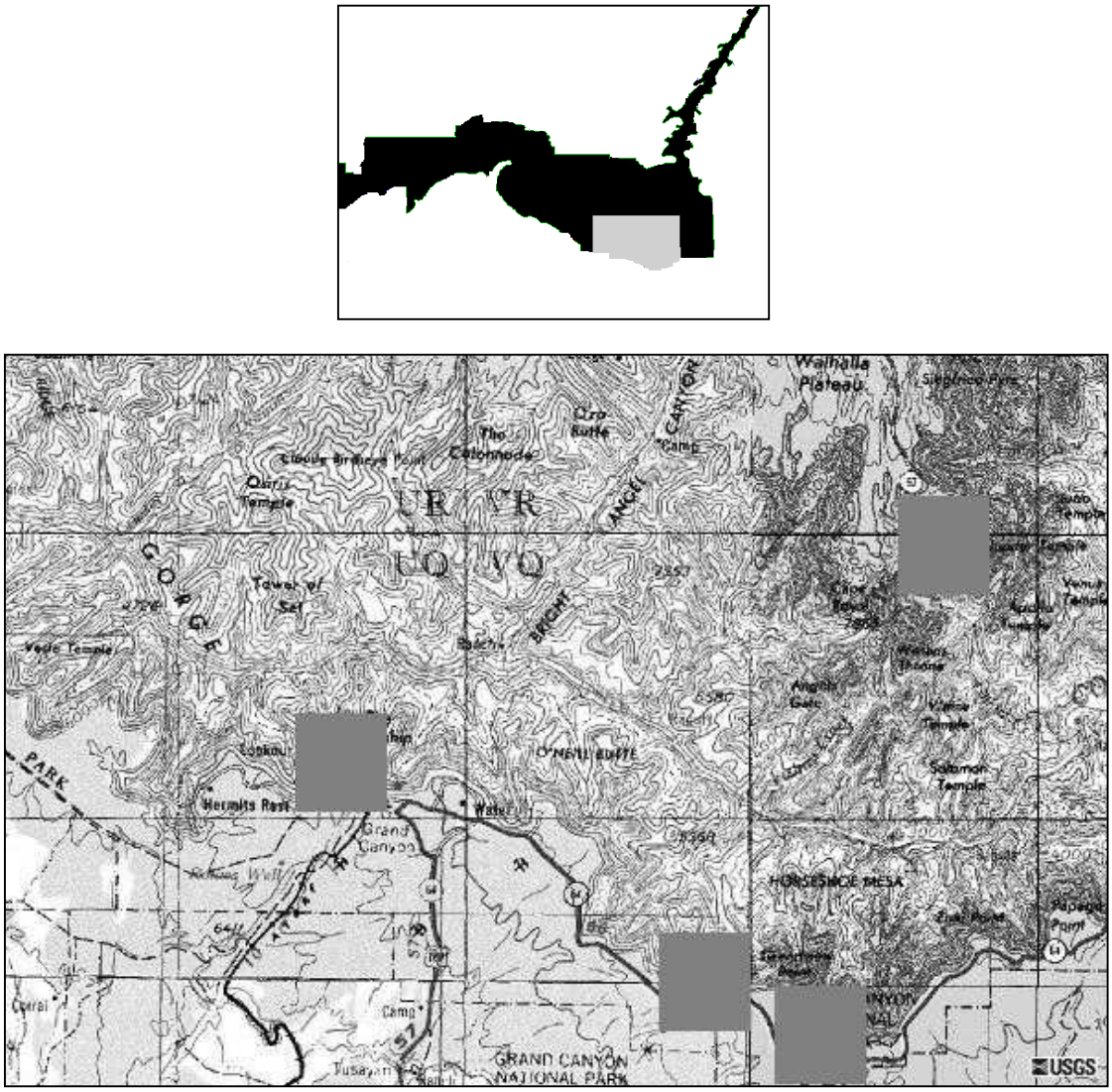

Figure 2. Location of sentry milk-vetch populations in Grand Canyon National Park. (Gray inserts represent the general location in the Park locator map and more specific locations in the topographic map).

In 1994, what has been identified as another population of the species was discovered on the North Rim of the Grand Canyon (Travis et al. 1996). This population (which consists of up to five subpopulations) was identified as variety *cremnophylax* based on morphology (Allphin *et al.* in prep.). However, the seeds of the North Rim plants are of a different color than those of the South Rim plants. Recent preliminary genetic and allozyme work indicates that the North Rim population is genetically distinct (Travis et al. 1996) and/or genetically different (Allphin *et al.* undated) from the populations on the South Rim. Allphin *et al.* (undated) concluded that the Maricopa Point population is more closely related to variety

myriorraphis than it is to the North Rim population and that analyses indicate all varieties of *A. cremnophylax* are more closely related to *A. humillimus* than to the North Rim population. Allphin *et al.* (in prep.) believe that the North Rim population is distinct from the populations on the South Rim and may merit varietal or species status. Additional research is planned to address this question. However, unless and until an alternative taxonomic treatment is published in a peer-reviewed journal and accepted, the North Rim population is recognized as sentry milk-vetch.

In 2002, another possible population was discovered on the South Rim of the Canyon east of the Maricopa Point site. Preliminary information indicates that this population consists of 252 individuals. Confirmation of species identification, based on morphological characteristics, has not yet been accomplished.

At one time, the potential habitat for sentry milk-vetch was thought to include all layers of the Kaibab Formation, which forms hundreds of miles of both rims of the Grand Canyon, and at bedrock outcrops away from the canyon rims. However, several observers have hypothesized that the potential habitat may be far more restricted. Populations occur on a specific, pure white layer of highly porous Kaibab limestone. The original population on the South Rim occurs where large open platforms are formed near pinon-juniper woodlands where soils are shallow, and where there are cracks in Kaibab limestone slabs. The Grandview population occurs on smaller slabs with cracks. Such areas along the South Rim are a small subset of the total extent of the Kaibab limestone. The recently discovered population on the South Rim generally follows the same pattern, but a portion of the population also occurs in what has been referred to as a "predominance of small (2-5 cm) broken limestone rocks within a fine limestone sand matrix" (Therean Taylor *in litt.* 2002).

Additional areas that should be surveyed for the presence of the species have been identified (N. Brian *in litt.* 2000). The new possible population on the South Rim was discovered in 2002 as a result of such surveys.

Habitat and Site Description

Sentry milk-vetch forms mats or shallow mounds in scarcely visible cracks on Kaibab limestone bedrock, in sand-filled hollows of rock (Barneby 1964), or on shallow gravelly soils. The species appears to occur on one specific, pure white layer of Kaibab limestone where the bedrock forms an unshaded platform. It has not been found on small, shaded ledges or cliffs. The Grandview Point plants occur in a large crack in a small isolated ledge. The habitat is characterized by shallow soils or bedrock on the limestone platforms (U.S. Fish and Wildlife Service 1990).

Prevost (1991) investigated soils at Maricopa Point and found them to be extremely shallow at less than 7 centimeters (2.8 inches) deep. Textures ranged from very gravelly,

very fine sandy loam to extremely gravelly loamy fine sand. Clay content ranged from about 8 to 14 percent. Soils were mildly alkaline, with a pH value of 7.8, and were only slightly effervescent. The first 2 centimeters (0.8 inch) of the soil profile was characterized by subangular to subrounded fragments of mixed mineralogy, predominantly comprised of limestone, chert, and basalt less than 2 centimeters (0.8 inch) in diameter. The soil profile from 2 to 6 centimeters (0.8 to 2.4 inches) was very gravelly, very fine sandy loam with a weak thick platy structure, which was soft, very friable, slightly sticky, and nonplastic with fine irregular and tubular pores. Below 6 centimeters (2.4 inches) lies the Kaibab limestone bedrock (Prevost 1991).

In comparison with other sites along the South Rim of Grand Canyon, soils at Maricopa Point have less lime content, slightly greater magnesium content, mixed mineral gravels present, and less residual soils of limestone origin. The subrounded gravels and concave landform at Maricopa Point may indicate an alluvial parent material, probably transported from nearby sources (Prevost 1991).

The low lime content and slightly higher magnesium content of soils at Maricopa Point suggest that the underlying bedrock may be more porous than at other sites on the South Rim. According to Levine *et al.* (1989), the porosity of the bedrock limestone influences the surface soil formation. Highly porous bedrock may contribute to calcium carbonate removal and dolomite crystal-lattice formation. As dolomite dissolves, magnesium is released in solution and incorporated into soils. Thus, there is some preliminary evidence that soil, bedrock chemistry, and hydrology at Maricopa Point are distinctive. Because soil moisture is less than 0.6 percent at Maricopa Point, bedrock may play a role in providing moisture to plants. Whether the presence of sentry milk-vetch is tied directly to these conditions is unknown.

Soils at Grandview Point, where two sentry milk-vetch plants are extant, have not been analyzed, but cursory investigation indicates that the Kaibab limestone there forms a flat, white platform, similar to the one at Maricopa Point. The substrate and soil conditions at the North Rim and possible new South Rim population have not been investigated.

Associated plants in the vicinity of the species include rock mat (*Petrophytum caespitosum*), pinyon pine (*Pinus edulis*), Utah juniper (*Juniperus osteosperma*), little-leaf mountain mahogany (*Cercocarpus intricatus*), cliffrose (*Purshia stansburiana*), Hartweg evening primrose *(Calyophus hartweggi)*, wheatgrass (*Agropyron smithii*), and bluegrass (*Poa pratensis*) (Phillips *et al.* 1982). Shrubs and trees in the vicinity appear typical of the pinyon-juniper woodland community. *Astragalus calycosus* is a common milk-vetch in the surrounding area, but its larger size, upright growth form, and purple-pink flowers that fade to blue on stalks that extend above the leaves make it easily distinguishable from *A. cremnophylax*.

Life History and Ecology

Sentry milk-vetch exhibits two episodes of flowering from March through April and from September through November. Spring is the most common flowering time and usually results in successful fruit and seed set (Maschinski 1990a). Fall flowering plants set fruit, but seeds may not germinate until the next year (Maschinski 1991). This bi-seasonal flowering pattern has also been observed in plants cultivated at The Arboretum at Flagstaff (Maschinski 1990a). Plants in cultivation produced flowers after one year of vegetative growth. Age of first reproduction in the wild population is known to occur as early as one year from germination in individuals that have not been stressed by external factors (e.g., damage to foliage, lack of moisture) (K. Warren *in litt.* 1993).

Plants bearing the greatest number of mature fruits and seeds in May and June are generally the largest plants in the population. These large plants produced an average of 200 fruits in spring 1992 (Warren 1993). Smaller sized individuals produced disproportionately fewer fruits than projected based on the size of the plant (Warren 1993). The average number of seeds per fruit is 3.02, but the number can vary from one to six seeds (Maschinski 1990a, 1991).

Dispersal of seeds is very limited. Because the soft, pliable pods do not forcefully expel seeds as they split, seeds may remain within the pod attached to the parent plant for months (Maschinski *et al.* 1994). Seeds often fall into the foliage of the parent plant. Ants have been seen visiting the plants, but their influence on sentry milk-vetch is unknown. Ants may act as dispersal agents, but some species of ants eat seeds, flowers, or flower parts. Wind and water likely play an important role in seed dispersal (Maschinski 1990b). Because the fruits and tiny orange seeds are inconspicuous and do not seem to attract birds and mammals, the seeds are probably not dispersed or eaten by them.

Further evidence for limited seed dispersal comes from natural seed germination. Seed germination occurs in the fall, as early as September. Seedlings often germinate within 10 centimeters (4 inches) of an adult plant, but occasionally seedlings become established more than 30 centimeters (12 inches) from a parent plant. Seedlings that attempt to grow within the mat of the parent plant, or less than 5 millimeters (0.2 inch) from the edge of the mat have a decreased probability of survival (Maschinski *et al.* 1994). Establishment may occur within the foliage of the parent plant or other species such as rock mat, or at the base of species such as cliffrose or snakeweed (*Gutierrezia sarothrae*). Seedlings become established in soils between 2.5 to 5 centimeters (1 to 2 inches) in depth, suggesting that shallower soils do not have enough moisture retention for survival of seedlings (Maschinski 1990b). Maschinski *et al.* (1994) believe that persistence of seeds in a seed bank is minimal due to the shallow soils, large areas of exposed bedrock, and exposure of the site to high winds.

Data indicate seed germination varies from year to year. In cultivation, 49 percent of seeds collected in 1989 germinated readily without any special treatment (Maschinski 1990a). Only 31 percent of seeds collected in 1991 germinated (Maschinski 1991). Coincident with the decline in the seed germination rate is a decline in the numbers of individuals present at Maricopa Point. Several factors, including environmental factors, may be responsible for these year to year differences in seed germination.

Seedling survival in cultivation was closely correlated with the substrate in which seeds were planted. Seedlings did not survive in well-aerated soil, but required limestone substrates for survival (Maschinski 1990a). These results suggest that the high water retention of heavy limestone soils was required for seedling growth and development.

Reasons for Listing / Threats

The Fish and Wildlife Service carefully assessed the best scientific and commercial information available regarding the past, present, and future threats faced by *Astragalus cremnophylax* var. *cremnophylax* as part of the evaluation to list this species as endangered (U.S. Fish and Wildlife Service 1990). The four major threats identified in the rule listing the species were: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) the inadequacy of existing regulatory mechanisms; and (4) other natural or manmade factors affecting its continued existence.

The Present Or Threatened Destruction, Modification, Or Curtailment Of Its Habitat Or Range.

Because the largest known confirmed population sustained severe declines, the species remains in danger of extinction (U.S. Fish and Wildlife Service 1990, Maschinski and Rutman 1993). Despite the construction of a barrier fence, trampling of sentry milk-vetch and habitat degradation still occur at Maricopa Point. Trampling does not appear to be a threat to the very small population at Grandview Point, or to the North Rim and possible new South Rim populations. However, other threats to the species at these other locations include such actions as fire management and construction and development in Grand Canyon National Park.

For decades, Maricopa Point has been a popular viewing point for visitors to the South Rim of the Grand Canyon. It is one of the first opportunities along the West Rim Drive to view the canyon, and a large parking lot near the point makes visitation safe and convenient. Visitors arrive at Maricopa Point by shuttle bus, personal vehicles, or by walking along the West Rim Trail from Grand Canyon Village. The Park keeps the parking lot open to private vehicles from December 1 through February 28. From March 1 through November 30, the West Rim Drive is closed to private vehicles, but shuttle buses transport people from

Grand Canyon Village to points along the West Rim Drive, including Maricopa Point. In the past, paved trails and dirt trails formed by casual, repeated use ("social trails") fragmented the population of sentry milk-vetch.

Prior to fencing of the sentry milk-vetch population in 1990, many thousands of visitors per year walked over the then only known population. Prior to protection about 100 visitors per hour visited Maricopa Point during the peak visitor season of May and June (K. Warren *in litt.* 1993). Trampling of plants can cause mechanical injury to plant parts and alter habitat conditions through soil compaction, erosion, and physical disturbance (Hamilton and Lassoie 1986, Kuss 1986, Thomas and Wilson 1992). These impacts to plants can reduce photosynthetic activity, increase water loss, create increased energy costs for regrowth, and reduce reproductive output (Kuss 1986, Thomas and Wilson 1992). Early studies conducted on sentry milk-vetch by O'Brien (1984) reported that, out of 410 plants located and measured, 227 (65 percent of all mature plants recorded) were unhealthy and declining from trampling. In July 1986, the Park erected wooden fencing along portions of the paths at Maricopa Point to guide visitors away from the population. These efforts had limited success. The demographic monitoring data collected beginning in 1988 demonstrated that the number of sentry milk-vetch plants was in decline, soil was disturbed, and many plants were low in vigor (Rutman 1988). Trampling may have resulted in a decline of occupied habitat (apparently suitable habitat occurs at Maricopa Point that is currently unoccupied). In May 1990, the Park built a fence that directed visitor foot traffic completely around the population to a canyon overlook adjacent to Maricopa Point. In 1995, wire fabric was added to the wooden fence to improve restriction of human access. Paved trails within the area were removed and signs were placed on the fence to restrict access. The fence deters the vast majority of visitors from walking through the population of sentry milk-vetch, although some visitors violate the exclosure. In 1993, the Park estimated that one visitor per day intruded into the exclosure (K. Warren *in litt.* 1993).

The extent and effects of trampling and other threats to sentry milk-vetch at Maricopa Point have been documented in demographic monitoring plots (O'Brien 1984, Rutman 1988, Maschinski and Rutman 1993, Maschinski *et al.* 1994). In 1988, the first year of a long-term study, 361 plants were included within the monitoring plots (Table 1). Sixty-five percent of all plants in the monitoring plots showed some degree of trampling, and more than half of all plants (58 percent) showed severe trampling (Rutman 1988, Maschinski *et al.* 1994). Within one year, about 10 percent of the adult population had been lost (Warren 1993). Between May 1989 and May 1990, subpopulations experienced 19 to 63 percent mortality, depending upon the amount and severity of human traffic (U.S. Fish and Wildlife Service 1992, Maschinski and Rutman 1993). The population continued to decline between 1990 and 1992, even after the exclosure fence was built. Compounding the effects of trampling was below-average rainfall in 1989, which may have increased plant mortality (U.S. Fish and Wildlife Service 1990, Maschinski and Rutman 1993).

Trampled sentry milk-vetch plants lost leaf and branch biomass to varying degrees, depending on their position near heavy foot traffic areas. By 1990, many plants that had been monitored for three years had lost 95 percent of their aboveground biomass. Though some degree of this loss may be attributed to various factors (e.g., low precipitation), trampling is considered the primary cause. However, by 1992 and after two years of protecting the site, many of these plants had not begun to recover and many had died. Plants that received the most severe damage were those immediately adjacent to the rim. The loss of photosynthetic material on mature plants probably adversely affected plant vigor, the ability to withstand environmental stress, and flower and fruit production. The long-term effect of trampling is manifested in the current distribution of sentry milk-vetch plants. Plants in the formerly heavily visited areas normally occur where some surface irregularity in the rock, such as a deep crack or bump, protected the plant, or where some moderate to large sized obstruction diverted visitor traffic flow.

Table 1. Earlier estimates and numbers of individual sentry milk-vetch plants detected in monitoring plots from 1988 through 2004, at Maricopa Point, Grand Canyon National Park. Data from Warren (1993 and 1994) and Brian (2000b and 2001) and Juarez-Cummings (2004).

Year	Seedlings	Adults	Total
circa 1964	no data	no data	approximately 100
1982	no data	no data	approximately 150
1983	no data	no data	410
1988	46	314	361
1989	16	333	348
1990	10	275	285
1991	31	247	278
1992	24	249	273
1993	55	264	319
1994	69	268	337
1995	no data	no data	no data
1996	no data	no data	450
1997	no data	no data	no data
1998	no data	no data	no data
1999	no data	no data	no data
2000	143	540	683
2001	108	557	665
2002	no data	no data	no data
2003	no data	no data	no data
2004	338	38	376

Trampling probably adversely affected sentry milk-vetch seedling recruitment and survival. Prior to protection, uprooted seedlings were observed in the monitoring plots and only those seedlings in sites relatively safe from human traffic survived (U.S. Fish and Wildlife Service 1990). Since construction of the fence in 1990, the number of established seedlings growing to reproductive maturity has been increasing (Maschinski *et al.* 1994).

Foot traffic compacts or otherwise disturbs the soil or bedrock surface and may adversely affect the plant/soil relationship (Kuss 1986). This effect may make germination less successful, seedling mortality higher, and reduce the vigor of mature plants (Hamilton and Lassoie 1986). Sentry milk-vetch distribution was markedly affected by trampling. Where the soil in occupied habitat is deepest, 2.5 to 5 centimeters (1 to 2 inches), foot traffic caused the greatest disturbance when the soil was wet and muddy. Plants in these areas were generally found where foot traffic was diverted by some small obstruction such as a shrub, tree, or dead tree branch. On the bedrock-dominated habitat, foot traffic has polished the limestone pavement, which may have adversely affected the porosity of the substrate (U.S. Fish and Wildlife Service 1990).

Human traffic indirectly affects the sentry milk-vetch population through habitat degradation. Over time, trampling has resulted in the loss of plant cover, which has resulted in erosion of the thin soil. Foot traffic can also displace what little soil builds on the limestone surface, thus reducing the number of microsites available for germination. Most seedlings establish near plants or other obstructions that stop the sheet flow. The loss of plant cover due to trampling can reduce the microsites available for seedling establishment.

Sentry milk-vetch habitat and plants were probably lost when the Park constructed the West Rim Trail at Maricopa Point. This paved trail passed within a few feet of the rim and fragmented the sentry milk-vetch population. The paved trail was removed in May 1990 when the site was fenced to exclude human foot traffic.

The demographic data from 1988 through 1994 were further analyzed and interpreted by Maschinski *et al.* (1996). Their analyses confirmed that the size of the Maricopa Point population fluctuated even with protection. However, their modeling indicated that removal of trampling led to a prediction of stabilization, while continued trampling with poor climatic conditions led to a prediction of accelerated extinction. Maschinski *et al.* (1996) stated that the continued existence of the species will depend on continued protection, environmental conditions that promote recruitment, and recovery efforts such as habitat enhancement and augmentation.

Sentry milk-vetch may face other threats that were not addressed in the original listing rule. Additional populations have been discovered since the species was listed. Grand Canyon National Park is in the process of implementing certain actions, such as construction projects, that may affect the populations and/or the species' habitat.

The North Rim population was monitored in 1995, 1996, and 1997 (J. Maschinski, *in litt.*, 2000). The most significant result of the monitoring was an observed loss of plants in one of the subpopulations between 1996 and 1997. The observed loss was coincident with improvement of a trail which led directly to the subpopulation. The trail has subsequently been rerouted away from the subpopulation. In 1999 (Brian 2000a), the basal areas of selected individuals of the North Rim population were measured and compared to measurements made in 1997. The average basal area of the selected plants increased by 59 percent which is much higher than the rate of growth observed on the South Rim. The observed growth rate differential was attributed to environmental factors on the North Rim.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes.

Plant collecting by botanists and other rare plant enthusiasts is a potential, but currently minor, threat to sentry milk-vetch. Although the extent of this threat is unknown, publicity could make this species susceptible to increased visitation and collection (U.S. Fish and Wildlife Service 1990). Because the number of populations and individuals is so small, even a small or moderate amount of collecting could seriously impact the species.

The Inadequacy of Existing Regulatory Mechanisms.

The species is protected by National Park Service regulations, as are all plant species within the Park. Sentry milk-vetch is protected by the Arizona Native Plant Law. That law prohibits the collection of the species unless the Arizona Commission of Agriculture and Horticulture grant a permit for educational or scientific purposes. However, the law does not provide habitat protection. Protection provided to the species under the Endangered Species Act is discussed below, in Conservation Measures.

Other Natural or Manmade Factors Affecting Its Continued Existence.

Mortality of sentry milk-vetch plants surpassed establishment in all years monitored until 1993. The number of seedlings produced per year at Maricopa Point was insufficient to maintain the population and compensate for the annual mortality of adult plants until 1993 (Maschinski and Rutman 1993). Seedling mortality was high (Maschinski and Rutman 1993) relative to the number of plants surviving to reproductive maturity and the total annual mortality within the population until 1994. Since protection by fencing, seedling establishment has increased (Maschinski *et al.* 1994). Seedling numbers from 1988 through 1992 may have been small for several, possibly interdependent, reasons, including trampling, weather conditions, degraded habitat conditions, poor seed dispersal, and insect predation. Seed production may be reduced by hard frosts and freezes during the flowering/fruiting period, a situation that occurred in 1988. Low seed-germination and seedling-establishment rates may have occurred due to insufficient rainfall. Poor seed dispersal may also affect the number of seedlings because seeds fall near the parent plant, where establishment is likely

reduced. Insect predation may affect seedling establishment and survival. Although recent monitoring indicates improvements in seedling establishment, fluctuations in seedling survival are anticipated due to the above-mentioned reasons. Annual inventory of the monitoring plots is crucial to determine if natural recruitment levels are sufficient to maintain the population.

Allphin *et al.* (in prep.) investigated seed production in several species of *Astragalus*, including sentry milk-vetch, in northern Arizona and vicinity. They concluded that sentry milk-vetch is a poor reproducer. The species exhibits a mean seed/ovule ratio that is approximately half of that for other related species. In addition, the observed ratio does not seem to be influenced by environmental factors.

Whether the population at Maricopa Point will persist and recover is unknown. The population declined to the point where a significant amount of area occupied in 1988 is now unoccupied and plant density is still relatively low. The ultimate response of sentry milk-vetch to reduction in foot traffic is unknown. Current data (Maschinski *et al.* 1994) indicate that the population is responding to protection and there is less mortality, greater numbers of seedlings being established, and an increase in plant vigor. Recolonization of unoccupied habitat may take a long time because seed dispersal is restricted and unoccupied areas appear to have been adversely affected. The extremely small populations of sentry milk-vetch make it particularly vulnerable to any impacts reducing the numbers or fecundity of plants. As population size decreases, the effect of natural catastrophes and environmental and demographic stochasticity becomes more critical to the survival of the species (Shaffer 1981, Menges 1991). Several consecutive years of unfavorable environmental conditions or any local catastrophic event may have disastrous impacts to sentry milk-vetch. Maximum protection of the population at Maricopa Point is critical to the continued existence of this species.

Conservation Measures

Regulatory tools that aid in the conservation of sentry milk-vetch include:

Taking and Trade Prohibitions

The Endangered Species Act (Act) prohibits the malicious damage, destruction, or removal and reduction to possession of listed plants under Federal jurisdiction. For areas not under Federal jurisdiction (e.g., private or state-owned lands), the Act prohibits removing, cutting, digging up, damaging, or destroying listed plants in knowing violation of any State law, including the violation of a State criminal trespass law. The Act prohibits a person subject to the jurisdiction of the United States from selling, offering for sale, importing, exporting, or transporting in interstate or foreign commerce any listed plant species in the course of commercial activity. The Lacey Act prohibits the same activities if the species is

listed under any State law that provides for the conservation of species threatened with extinction, or is listed on an appendix to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Under certain circumstances, the Act also provides for the issuance of permits to carry out otherwise prohibited activities involving listed species. Sentry milk-vetch is listed as a highly safeguarded plant by the State of Arizona and is protected by the Arizona Native Plant Law.

Endangered Species Act Section 7 Requirements

Section 7 of the Act prohibits actions authorized, funded, or carried out by Federal agencies that jeopardize the continued existence of any listed threatened or endangered species. In addition, if discretionary Federal actions may affect listed species, section 7 consultation is required.

Other conservation measures and research efforts for sentry milk-vetch include:

In May 1990, the Park constructed a sturdy wooden fence at Maricopa Point to protect sentry milk-vetch from visitor traffic, and wire fabric was added to the fence in 1995. Although some people go around it, the fence has successfully rerouted the majority of visitors away from the habitat. In addition, the Park removed the portion of the paved West Rim Trail that circled the point. In 1990, one seedling became established in an area formerly covered with asphalt. Signs on the fence inform visitors that an ecologically sensitive area exists beyond the fence and instructs them to remain on the current trail that bypasses Maricopa Point and continues to other viewpoints. A small number of visitors still climb over the fence or go around the ends of the fence.

Permanent demographic monitoring plots were established in 1988 (Rutman 1988, Warren 1993). Park and Service personnel and volunteers collect data on plant size, flower production, damage class, recruitment, and mortality for marked individuals. This effort has aided understanding of many aspects of the ecology of sentry milk-vetch and supported the need to construct the fence to exclude visitors from the site.

The Arboretum at Flagstaff began studies of seed germination and seedling survival in 1989 to prepare propagules for reestablishment and development of a greenhouse population of sentry milk-vetch. As of 1994, there were 34 plants in the population at The Arboretum at Flagstaff. Because some of the plants in cultivation were easily desiccated, transplanting whole plants is likely to be difficult or impossible without daily irrigation throughout the dry season (Maschinski 1990a).

In July 1990, The Arboretum at Flagstaff conducted an augmentation study by sowing 196 seeds, collected in 1989, into four different microhabitats at Maricopa Point. The microhabitats were: 1) unshaded powdered limestone/fine gravel in pockets in the bedrock;

2) unshaded cracks in the bedrock; 3) 1 inch (2 to 3 centimeters) of soil on the east side of a tree or shrub, where seeds received morning sun; and 4) 1 inch (2 to 3 centimeters) of soil on the southwest side of a tree or shrub, where seeds received mostly afternoon sun. Seven seeds were sown into seven replicates of each microhabitat. Despite good rains at Maricopa Point during the summer of 1990, by September, 10 percent of the seeds had germinated, but only two seedlings (one percent) produced true leaves. By April 1991, only one seedling survived. It was established in a crack in the limestone (Maschinski 1993).

In 1991, The Arboretum at Flagstaff conducted a second sentry milk-vetch augmentation study. Using observations of where natural seed germination occurred, 230 seeds collected from mature plants in 1991 were sown. Sites for seed placement included soil at least 2 inches (5 centimeters) deep, in cracks in limestone, and near nurse plants or other structures that could provide temporary shelter. There was no germination (Maschinski 1991). The Park conducted similar trials by hand, distributing 100 seeds in 1992 at Maricopa Point. No seeds germinated (Warren 1993).

Future augmentation studies may help identify ecological requirements for seedling establishment and may increase the numbers of individuals in the population. However, based on these completed studies, introductions to new locations as well as population augmentation may be very difficult, and likely very dependant on local weather conditions. Successful augmentation or introduction is likely only if there are sufficient propagules available. Because there are so few individuals, seed production may not be sufficient. Investigation of alternative methods, such as tissue culture of plants, may be necessary.

PART II - RECOVERY

Recovery Strategy

The sentry milk-vetch recovery strategy is based on the species' current situation. These circumstances include a severely impacted small population, previous attempts to protect that small population, a few newly discovered populations that may or may not be the listed taxon, existing unsurveyed habitat, previous unsuccessful efforts to establish individuals in the wild, and very limited information regarding the biology and ecology of the taxon.

In order to address that situation, the recovery strategy includes several components: protection of all populations from old and new threats; surveys of habitat to locate any other existing populations; augmentation of existing populations; research regarding the basic biology and ecology of the species; establishment and maintenance of greenhouse/biological garden populations; establishment of additional wild populations; and close cooperative interaction among the entities involved in and responsible for recovery of the species.

Objective and Measurable Criteria

The primary objective of this recovery plan is to ensure that sentry milk-vetch is progressing toward recovery through the maintenance of viable, natural populations. Sentry milk-vetch will be considered recovered when there are at least eight geographically distinct, viable populations located and/or established and protected. The immediate conservation goals for sentry milk-vetch are minimizing the risk of extinction by protection of the known natural sentry milk-vetch populations, increasing the numbers of individual plants at each population to the maximum extent of the available habitat, removing threats, and establishing an *ex situ* (botanical garden/greenhouse) conservation program. Sentry milk-vetch will remain at high risk of extinction as long as there is only one confirmed, and up to four other possible, populations.

It is difficult to determine how many populations and how many individuals constitute a viable population when so many basic biological questions regarding this species remain unknown. Factors contributing to the estimation of the effective population size, including mating system, sex ratio, and variation in fertility (Barrett and Kohn 1991), are poorly understood for this species. It is not known if the populations have suffered a loss of fitness due to inbreeding depression, which can be a consequence of small population size. What is known is that the few known populations support low numbers of individuals and reproduction seems sporadic. The small number of populations makes the species most vulnerable to environmental stochasticity and natural catastrophes, assuming all other threats are removed. The minimum viable population (the minimum number of individuals needed in a population to have an acceptably low probability of extinction) is estimated to be

between 1,000 and 1,000,000 (Shafer 1987, Menges 1991). These numbers should be sufficient to protect the genetic integrity of most of in situ populations (Menges 1991). Unless and until new biological information indicates otherwise, the lower numbers will be used to set downlisting and recovery criteria. The extant populations and in situ established populations should support approximately 1,000 individuals.

Downlisting and Recovery (Delisting) Criteria

Reclassification to threatened status may occur when:

1. There are at least four viable populations of 1,000 individuals each (4,000 total).
2. Naturally occurring populations are stable or increasing over a ten-year period.
3. Reintroduced populations are stable or increasing over a thirty-year period.

Delisting will occur when:

1. There are at least eight viable populations of 1,000 individuals each (8,000 total).
2. Naturally occurring populations are stable or increasing over a ten-year period.
3. Reintroduced populations are stable or increasing over a thirty-year period.

The selected time periods reflect the low-frequency temporal variation in decadal drought-moisture cycles of the southwest (Swetnam and Betancourt 1998). Extant populations have presumably been through previous drought periods (such as the one we are currently experiencing) and survived. Newly established populations need longer time periods associated with the recovery goals to ensure that the populations experience the full range of climatic variation that occurs in these ecosystems.

Each population site must be protected from anthropogenic threats. The eight populations should be geographically separate and, in total, reflect the genetic variability of the species. The numbers were selected after careful consideration of the limited knowledge regarding the biology of the taxon, its rarity and limited distribution, threats to the species, and current plant conservation research. Eight populations seem necessary to support a species that has naturally small habitats and population sizes, and relatively high probabilities of population extirpations. Eight separate populations lessens the risk that extirpation of individual populations will result in a high risk of extinction of all populations. If new populations of sentry milk-vetch are discovered or established, the extent of occupied habitat and threats of extirpation/extinction can be re-assessed and the number of populations needed to meet recovery criteria can be modified, if necessary.

Increasing the number and size of populations will require considerable effort and aggressive protection. The very low success of the initial augmentation experiments indicates that increasing population numbers may take many years. Increasing populations, if

needed, at newly discovered locations may prove to be equally difficult, especially if sites with the unique soil/bedrock chemistry and hydrology required to sustain sentry milk-vetch prove to be limited. Because of the limited number of plants, the small area of occupied habitat, the low vigor of many reproductive-aged plants, and the degraded condition of much of the known habitat, the recovery criteria may prove to be an optimistic goal.

The recovery actions outlined below are preliminary. Additional actions may be necessary as new biological information is acquired for the species.

Step-down Outline of Recovery Actions

1. The present or threatened destruction, modification, or curtailment of its habitat or range.

1.1. Protect the population at Maricopa Point from disturbance. Trampling is a major threat to sentry milk-vetch and the existing fence that excludes public foot traffic from Maricopa Point should be maintained. The fence may also serve to discourage the public from collecting any plants. The exclusion of persons from the habitat area of sentry milk-vetch should be enforced by rangers and/or volunteers. Admittance to the exclosure should be given by explicit permission only. The need for additional protection at Maricopa Point should be reviewed at least annually. If the fence built in 1990 provides insufficient protection, additional measures, such as fence improvements, additional signing, and closing the parking lot to visitor parking and shuttle bus stops, should be considered.

1.2. Monitor threats and evaluate the need for additional protective measures. Managers should be aware of the types and severity of threats to each population. At a minimum, each site should be visited yearly for an evaluation of current threats and consideration of additional protective measures.

1.3. Conduct surveys to positively identify and determine taxonomic relationships of new populations as they are found. The 1991, 1994, and 2002, discoveries of sentry milk-vetch populations indicate that locating additional populations is a possibility if surveys continue. Although some areas have been surveyed for sentry milk-vetch, potential habitat exists along many miles of the rims of Grand Canyon and perhaps at exposures of limestone bedrock away from the canyon's rim. Access to these areas is often difficult. However, finding more populations would reduce the reliance on any single population and decrease the likelihood of extinction. In addition, surveys may identify suitable locations for the establishment of introduced populations in a natural setting.

In order to achieve proper management and base augmentation and introduction on the best science, populations other than that at Maricopa Point must be accurately identified. Initial

identification should be based on morphological characteristics by a recognized expert. Identification should include the latest genetic techniques to confirm that suspected populations of sentry milk-vetch are of that species.

1.4. Increase the number of individuals and the amount of occupied habitat at all occupied sites to the carrying capacity of the habitat. Populations of sentry milk-vetch are so small that any further reduction in plant numbers would seriously increase the risk of extinction of sentry milk-vetch. Efforts to increase sentry milk-vetch numbers should be focused on the Maricopa Point population in particular. Population levels should be increased to a level based on the amount of available habitat. To enhance recruitment into the population at Maricopa Point, seed germination and plant survivorship in all age classes must improve. Survivorship of mature plants has begun to improve now that many visitors are excluded from the site. However, a significant proportion of habitat is now unoccupied and, due to poor seed dispersal, the population may need assistance to reoccupy that habitat. Allowing or assisting this population to increase to the capacity of the habitat will reduce the species' probability of extinction. Several manipulative techniques, based on the results of ecological studies, should be considered in order to enhance the species' reproduction, recruitment, and survival. These techniques may include hand pollinating to increase fruit set, caging plants after fruits are set to prevent seed predation, sowing seeds away from parent plants in favorable microsites, and supplementing water to experimental sites to encourage seed germination and seedling survival. The need to use manipulative techniques should be carefully evaluated by the Park in cooperation with the Service.

1.5. Establish new populations as necessary to meet recovery criteria. Additional surveys may reveal the existence of more populations of sentry milk-vetch. However, additional populations should be established to ensure the species remains extant.

1.5.1. Establish a new population in a natural setting as a pilot project. Establishing a population of sentry milk-vetch could be a valuable tool to learn more about the species' ecological requirements. Experimentation and manipulation are more easily performed on new populations when such factors as seed sources, age of plants, soil conditions, weather conditions, and other factors are known in advance. Results of this pilot project can be used to develop management strategies and protection priorities of natural populations, augmentation methodology for natural populations, and the viability of introduced populations. Such a population would also serve as a seed source if the natural populations are lost.

1.5.2. Survey potential suitable habitat. Areas that could be used to support new populations should be identified. Sites that are not and will not be subjected to disturbance or modification will be most desirable for successful establishment and preservation of a new population.

1.5.3. Introduce the species to suitable microsites. Techniques to introduce the species must be developed before introduction will be possible or successful. The plant grows on bedrock or shallow soils, making the transplantation of greenhouse-grown plants difficult, if not impossible. Other techniques such as seed dispersal to new sites and other manipulative techniques should be explored.

1.5.4. Monitor and study the reintroduced population. Monitoring and study should aid in understanding the reasons for the success or failure of the effort. Techniques for creating new populations and managing natural populations can be learned through this process.

1.5.5. Based on the results of the pilot project and availability of suitable introduction sites, establish additional new populations. The number, size, and distribution of natural populations which are known upon the completion of the pilot project will determine the urgency or necessity of further conservation efforts in a natural setting. Individual populations should maintain and reflect the genetic integrity of each known natural population. The introductions should be planned to establish self-sustaining populations to achieve reclassification criteria. A monitoring program for all introduction efforts would need to be developed.

2. *Overutilization for commercial, recreational, scientific, or educational purposes.*

2.1. Coordinate research activities. Careful coordination among investigators and with the Park is needed to insure that the cumulative impact of various studies and research activities does not harm the population. Investigators must obtain permits from the Park and Service prior to initiating most biological studies.

2.2. Develop public awareness, appreciation, and support for preservation of sentry milk-vetch. Public education can be a crucial part of the recovery of a species. The cooperation of the public will also be essential for the ultimate success of ongoing recovery actions. Many public interest groups, such as native plant societies, can lend physical support to recovery efforts. Grand Canyon National Park staff can help explain the importance of plant conservation, maintaining

biodiversity, and natural resources unique to the Grand Canyon. Materials to educate the public should be developed. If the Maricopa Point parking lot remains open, tour and shuttle bus drivers stopping at Maricopa Point could alert visitors to the protection of the "environmentally sensitive area" and provide general comments regarding plant conservation. Because vandalism is a potential threat to many endangered species, care should be taken to avoid directly identifying the site.

3. *Disease or predation*. – This is not known to be a factor in the endangerment of the sentry milk-vetch.

4. *The inadequacy of existing regulatory mechanisms*.

4.1. Enforce laws and regulations. All regulations for the protection of threatened and endangered species on Federal lands, including the Endangered Species Act, the Lacey Act, the Arizona Native Plant Law, National Park Service Organic Act, and Grand Canyon Enlargement Act, should be enforced.

5. *Other natural or manmade factors affecting its continued existence*.

5.1 Provide assistance to Grand Canyon National Park (and other land owners and managers) to recover and protect the species and its habitat. Recovering and protecting populations of sentry milk-vetch is the responsibility of the Park. We will provide technical assistance to the Park, as requested. If new populations of this variety are discovered on other lands, we will provide management assistance to those landowners or managers, if requested. We will assist the Park and land owners and managers in seeking funding to support recovery actions on and off Park lands.

5.2 Adjust management as necessary. As monitoring proceeds, new threats may be identified, or previously unrecognized ongoing threats may become obvious. The Park or other landowner or land manager should respond to any recognized threat promptly by modifying management to minimize or eliminate the threat(s).

5.3 Conduct research on the existing populations. Studies of the wild populations of sentry milk-vetch should be developed to provide information essential for the conservation of the species, including determining the species' status, developing successful augmentation techniques for natural populations, and evaluating management decisions. Because so little is known about the biology and ecology of sentry milk-vetch, a diverse array of studies can contribute to protecting the species from extinction.

5.3.1 Continue to gather and analyze demographic data. Monitoring the demographic plots established at Maricopa Point in 1988 should be continued and the data analyzed. In addition, similar monitoring should be established and conducted for all other populations. The monitoring at all sites should include tracking individuals, determining reproductive status, determining the fate of seedlings, and habitat monitoring (e.g., repeat photography). A summary of the data collected as part of each annual monitoring effort should be prepared each year. Every three to five years, an inclusive, detailed analysis of the demographic data should also be prepared. The demographic and biological information gathered from these plots will help the Park and FWS determine the status of the species, identify threats, and guide management decisions. In addition, the baseline demographic data will help determine if any management activities (e.g., the construction of the exclosure fence) affect species recruitment and survival. Life-history characteristics and the influence of various environmental parameters may be determined through these demographic studies. For example, a determination of the average age of first reproduction and fecundity, and whether mortality factors are controlled by precipitation patterns, are needed.

5.3.2 Study the ecology of the species. There are several ecological questions must be answered to understand the reasons for the decline and lack of vigor in sentry milk-vetch populations. Specifically, habitat requirements for seed germination and seedling survival, pollination and dispersal ecology, and the effects of herbivory and competition should be investigated.

5.3.3 Soil and hydrologic requirements. The different rates of seed germination and establishment on different substrates may be due to hydrologic properties or soil chemistry. Understanding the relationships among seedling mortality, soil depth, soil/bedrock chemical properties, and moisture may be essential for best management of the existing site, conducting successful population augmentation, and establishing new populations in a natural setting.

5.3.4 Seed dispersal. Seed dispersal seems to be extremely limited. Studies should be implemented to investigate patterns of natural dispersal, consequences to seedlings, and natural dispersal agents. It is possible that germination and seedling survival could be improved by physically distributing seeds, particularly into suitable but currently unoccupied habitat.

5.3.5 Biotic factors. Biotic factors may explain patterns of mortality and survival of sentry milk-vetch and should be investigated. For example, seedling distribution may reflect the influence of competition or herbivory. Evidence of whether seedlings fail to survive when growing too close to the parent plant or its neighbors or are subject to greater herbivory when growing in certain microsites would be useful for population augmentation and in establishing new populations in a natural setting.

5.3.6 Phenology. Intrinsic factors of sentry milk-vetch, such as the timing of flowering, fruit set, and seed germination can guide the timing of recovery activities. Studies should be initiated to examine these factors. For example, if plants that flower in the fall set more seed than those that flower in the spring, yet seeds produced in the spring have greater viability, perhaps hand-pollination would be most productive if conducted in the spring rather than in the fall.

5.3.7 Timing and causes of mortality. Presently, we know little about the causes of death of plants of varying ages. To successfully augment known populations and establish new populations in natural settings, we need to know when and which factors most seriously threaten the population.

5.4 Establish an *ex situ* (botanical garden/greenhouse) conservation program. One catastrophic event at Maricopa Point could result in the extinction of sentry milk-vetch. The Grandview Point population is not large enough and may never be large enough to support a population that will ensure the continued existence of the species. At this point, it is not clear how the other known populations should fit into the augmentation and establishment of populations. Botanical garden/greenhouse populations of sentry milk-vetch would facilitate research and create a conservation pool should catastrophic events eliminate the species in the wild. If the Maricopa Point population is lost, seeds from such cultivated populations could be used to reestablish the species.

5.4.1 Establish and maintain a seed bank and botanical garden/greenhouse population. Establishment of new populations in a natural setting may be difficult given our current, limited understanding of the species. While efforts are being made to establish a population in a natural setting, a population in a garden and seed bank can be established to provide some buffer against extinction if catastrophic events cause the loss of the natural populations. Seeds from each natural population

should be individually conserved, and the source documented, to maintain the genetic integrity of each population. The Arboretum at Flagstaff, a member institution of the Center for Plant Conservation, maintains a seed bank and living plants of sentry milk-vetch, and should continue to maintain this living collection. Seeds are also being maintained at the U.S. Department of Agriculture National Seed Storage Lab. Seed should only be collected from natural populations for garden propagation or storage when fruit production is sufficient to withstand collecting. The number of reproductive plants and the number of fruits per plant is low enough that seed collection must be limited during some years so that the species is not adversely affected.

5.4.2 Investigate alternative methods to generate sufficient propagules for augmentation and introduction. Obtaining a sufficient amount of propagules for augmentation and introduction is likely to remain a problem indefinitely. For example, it has been estimated that as many as 10,000 seeds may be necessary to achieve augmentation or introduction by seeding alone. Additional methods and techniques, perhaps such as tissue culture of plants, for obtaining a sufficient number of candidates for introduction must be investigated and developed.

5.4.3 Until research otherwise indicates, do not mix propagules from different geographic populations in augmentations and introductions. Until the North Rim and Lollipop Point populations are definitively confirmed to be of the listed taxon, perhaps only individuals from Maricopa Point should be used for propagation and introduction to other unoccupied habitat. Until newly discovered populations are absolutely identified as sentry milk-vetch, and unless mixing of genetic lines is determined to be necessary, propagules from different populations should not be mixed when attempting population augmentation and introduction.

5.5 Exchange information between agencies, the public, and the scientific community. Scientific information, including results of field and greenhouse research, monitoring data, trip reports, agency reports, and scientific literature should be readily available to all parties interested in the management and survival of sentry milk-vetch. Ideas should be freely exchanged so that optimal recovery strategies can be outlined and implemented. Meetings of interested parties to discuss new information or management issues or strategies should be encouraged. Preliminary or refined research or monitoring data should be presented at local, regional, and national gatherings of professional scientists so that a broad

professional audience may have opportunities to comment on, and potentially enhance, the recovery potential of sentry milk-vetch.

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PART III - IMPLEMENTATION SCHEDULE

The following implementation schedule outlines actions and costs for the sentry milk-vetch recovery program. It is a guide for meeting the objectives discussed in Part II of this plan. The schedule indicates task priorities, numbers, descriptions, and duration, responsible agencies, and estimated costs. These actions, when accomplished, should bring about the recovery of sentry milk-vetch and protect its habitat. It should be noted that the estimated monetary needs for all parties involved in recovery are identified for the first five years only, and therefore are not reflective of total recovery costs. The costs estimated are intended to assist in planning. This recovery plan does not obligate any involved agency to expend the estimated funds.

Priorities in the first column of the table are assigned as follows:

Priority 1: An action that must be taken to prevent extinction, or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2: An action that must be taken to prevent a significant decline in species population/habitat quality, or some other negative impact short of extinction.

Agency Abbreviations

FWS - U.S. Fish and Wildlife Service
GRCA - Grand Canyon National Park
ARBO - Contracted studies/arboretum services

RECOVERY PLAN IMPLEMENTATION SCHEDULE

Costs (thousands of dollars)

Priority	Task	Description	Duration	Responsible Party	FY 1	FY 2	FY 3	FY 4	FY 5	Total
1	1.1	Maintain fence at Maricopa Point	Ongoing	GRCA	0.5	0.5	0.5	0.5	0.5	2.5
1	1.2	Monitor threats	Ongoing	FWS GRCA	 5	 5	 5	 5	 5	 25
1	1.3	Conduct surveys	3	FWS GRCA	8 8	8 8	8 8			24 24
1	1.4	Increase number of individuals in natural populations	5	FWS GRCA	14 6	14 6	14 6	14 6	14 6	70 30
1	1.5.1	Establish new populations	2	FWS GRCA				25	25	50
1	1.5.2	Survey habitat for new pilot population	3	FWS GRCA	8 2	4 1	4 1			16 4
1	1.5.3	Introduce pilot population	3	FWS GRCA			4 1	4 1	4 1	12 3
1	1.5.4	Monitor and study pilot population	3	FWS GRCA			4 1	4 1	4 1	12 3
2	2.2	Education	Ongoing	FWS GRCA	1 1	1 1	1 1	1 1	1 1	5 5
1	4.1	Enforce laws	Ongoing	FWS GRCA	0.5 0.5	0.5 0.5	0.5 0.5	0.5 0.5	0.5 0.5	2.5 2.5
2	5.1	FWS technical assistance to agencies and landowners	Ongoing	FWS	4	4	4	4	4	20
2	5.2	Adjust management	Ongoing	GRCA	2	2	2	2	2	10

Priority	Task	Description	Duration	Responsible Party	FY 1	FY 2	FY 3	FY 4	FY 5	Total
2	5.3.1	Collect and analyze demographic data	5	FWS GRCA	4 10	4 10	4 10	4 10	4 10	20 50
2	5.3.3	Soil and hydrological studies	2	FWS GRCA	5 5	5 5				10 10
2	5.3.4	Seed dispersal	2	FWS GRCA	6 4	6 4				12 8
2	5.3.5	Biotic factors	2	FWS GRCA	10 10	10 10				20 20
2	5.3.6	Phenology	2	FWS GRCA	12 8	12 8				24 16
2	5.3.7	Timing and causes of mortality	5	FWS GRCA	4 4	4 4	4 4	4 4	4 4	20 20
1	5.4.1	Establish and maintain seed bank and garden population	Ongoing	ARBO or other	8	8	8	8	8	40
1	5.4.2	Investigate and develop alternative methods to generate propagules	5	ARBO or other	10	10	10	10	10	50
2	5.6	Information exchange	Ongoing	FWS GRCA	0.5 1.0	0.5 1.0	0.5 1.0	0.5 1.0	0.5 1.0	2.5 5
Total					162	157	107	111	111	648

APPENDICES

Appendix A: Summary of Public Comments Received on the Draft Sentry Milk-vetch Recovery Plan in 1993 and Responses

Note: This comment summary was deleted since this plan will undergo a new comment period. These previous comments remain in the administrative record.

Appendix B: Summary of Public and Peer Reviews of 2004 and Responses

Note: TO BE ADDED AFTER REVIEW PERIOD.


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